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GENERATION OF TIDAL CURRENT AND HEIGHT CHARTS FOR NARRAGANSETT BAY USING A NUMERICAL MODEL

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INTRODUCTION

The use of numerical models to predict the tidal dynamics of estuaries has been well documented in the technical literature. The results of these studies, however, have been of little direct use to the general public. To remedy this lack of direct applicability a series of tidal current and height charts were prepared for Narragansett Bay, Rhode Island utilizing a numerical model, Swanson and Spaulding (1975). The format of these charts was designed to allow the recreational user to easily determine the tidal currents and height at any location and time.

The numerical model used is two dimensional, vertically averaged, multioperational, alternating direction implicit finite difference scheme developed by Leenderste (1967). Adaptation of the model to Narragansett Bay, using the appropriate geometry, bathymetry, river flow and tidal information, was reported by Hess and White (1969) along with various verification precedures utilized.

TIDAL HEIGHT DATA

One of the primary driving forces inducing currents in Narragansett Bay is the tides. Thus knowledge of the tidal height variation at the mouth of the Bay is required. Based on the tidal series equations presented by Hess and White (1974) a computer program we developed to generate the tide height data. Using the amplitude, epoch, and speed of the seventeen largest tidal constituents shown in Table 1, it was possible to predict the tide height at the mouth of the Bay at any time using a sinusoidal series formulation.

Using this procedure the tidal heights were then predicted for the decade, 1975 through 1984. Each tidal cycle was analyzed as to its range, period and shape and grouped with other tidal cycles of similar range. The ten year period resulted in approximately 7100 tidal cycles with a mean period of 12.42 hours and a mean range of 3.55 feet. The tidal range varied from 1.6 to 6.0 feet and a .2 increment was arbitrarily chosen to differentiate the tidal ranges. Figure 1 shows the tidal cycle variation for the smallest and largest ranges and the 10 year mean. Similar cycles in each .2 foot increment were averaged to obtain a mean tidal for each of the 22 increments. A distribution of the number of tidal cycles in each range is shown in Figure 2. As was expected, the maximum number of cycles occurred at the mean range with fewer at both the smaller and larger ranges.

Further analysis of these increments revealed that the period of a tidal cycle did not increase proportionately with increasing range. Instead there is a rapid increase at lower and higher tidal ranges with a fairly level plateau between approximately 2.3 feet to 4.9 feet as depicted in Figure 3.

The 22 range increment shapes and the 10 year mean were then each approximated by a Fourier series to be used as the tidal boundary condition to the model at the mouth of Narragansett Bay.

To facilitate the use of the charts a 10 year tide table was constructed from the tidal height data. Time of high water for each tidal cycle was determined and the range between that high water and the succeeding low water was calculated. These results were then tabulated by year, month and day and included as an appendix to the charts.

MODEL

The model used was adapted from the one described by Hess and White (1974). It was decided to include the Sakonnet River and Mt. Hope Bay with Narragansett Bay for a more complete converage of the area. A square grid of 1216 feet on a side was felt to adequately represent the important gross features of the Narragansett Bay complex which necessitated overlaying such a grid on the appropriate bathymetric chart and determining the depth values at 2300 locations. The use of a grid of this size resulted in a time step limit which required 90 minutes to stimulate one tidal cycle on an IBM 370/155 computer.

The 10 year mean tidal cycle was then used to drive the model until there was no discernible difference in the tidal heights and velocities at the same time between two consecutive tidal cycles. This output was then saved to be used in preparing the charts.

Twenty-two more runs were made each with a different tidal range. The 10 year mean values of height and velocity were used as initial conditions to speed convergence and reduce computer time. Tidal height and velocity data for each of these cases were saved.

CORRECTION FACTORS

Since the presentation of tidal height and currents for all of the tidal ranges would constitute a lengthy and expensive series of charts condensation was necessary.

Since the Bay is relatively small compared to a tidal wave length it was decided to use a simple scale factor by which the 10 year mean height and velocity could be multiplied to give the appropriate values at the various ranges. The height scale factor was found by averaging the ratio of height at a given range to the height for the 10 year mean over all the grids in the area while the velocity scale factor utilized the velocity ratios. The scale factors, both tidal height and velocity, thus calculated increase almost lineraly with tidal range as shown in Figure 4. For comparison the velocity scale factor obtained from experimental data by the National Ocean Survey is also shown and provides a quantitative verification of the model results.

CHART GENERATION

The tidal height and velocity data were presented in a series of 13 hourly charts referenced to high water at Newport, Rhode Island covering one complete tidal cycle. To assist users in interpreting the charts a digitized outline of Narragansett Bay was created with a Gerber digitizer coupled to a NOVA 1200 computer owned by the Ocean Engineering Department. In addition, the islands, towns, and points were labeled on the plotted outline which utilized the University of Rhode Island Academic Computer Central Bromall Plotter and IBM 370/155 computer.

The height charts were generated by assigning a distinct graphic design to each 0.1 foot increment above or below mean sea level for all of the 2300 grid points of data. Due to chart size limitations it was not possible to show all the velocity data on a readable scale so velocities were averaged over a four grid square 2432 feet on a side resulting in a maximum of approximately 600 values. The speed of tidal currents were represented by a value in knots printed alongside an arrow indicating current direction. In areas having current speeds less than .1 knots, the arrows were eliminated.

LIST OF FIGURES

Figure 1 Tidal Height Variation (Ft.) vs. Time (Hrs.) for 1.61-1.8 Ft. Range, Mean Range, and 5.8-6.0 Ft. Range.

Figure 2 Number of Tidal Cycles vs. Range (Ft.) for 10 years of Tide Data at Newport

Figure 3 Tidal Period (Hrs.) vs. Tidal Range (Ft.).

Figure 4 Comparison of Model Predicted Velocity and Height Correction Factors to National Ocean Survey Velocity Correction Factor.

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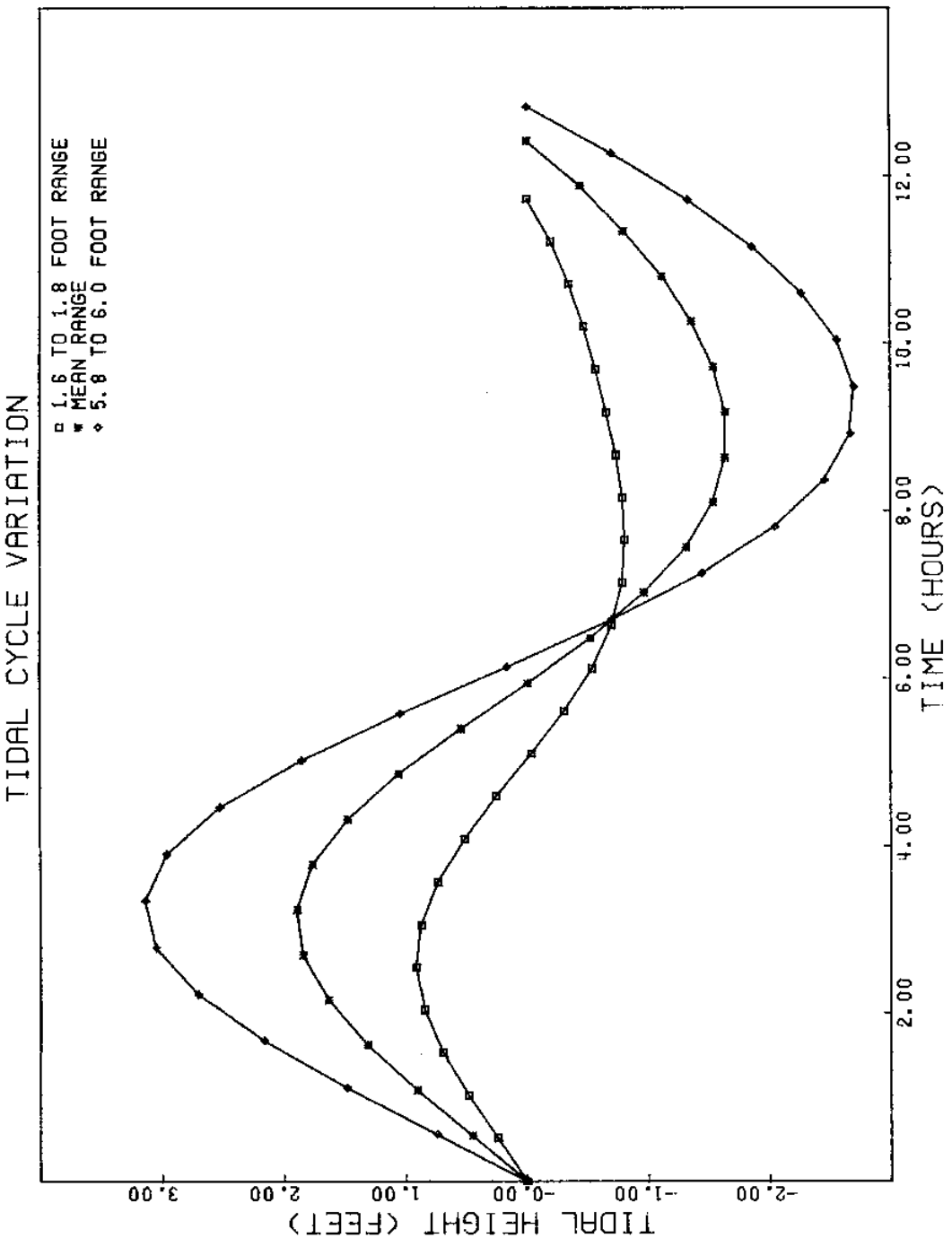
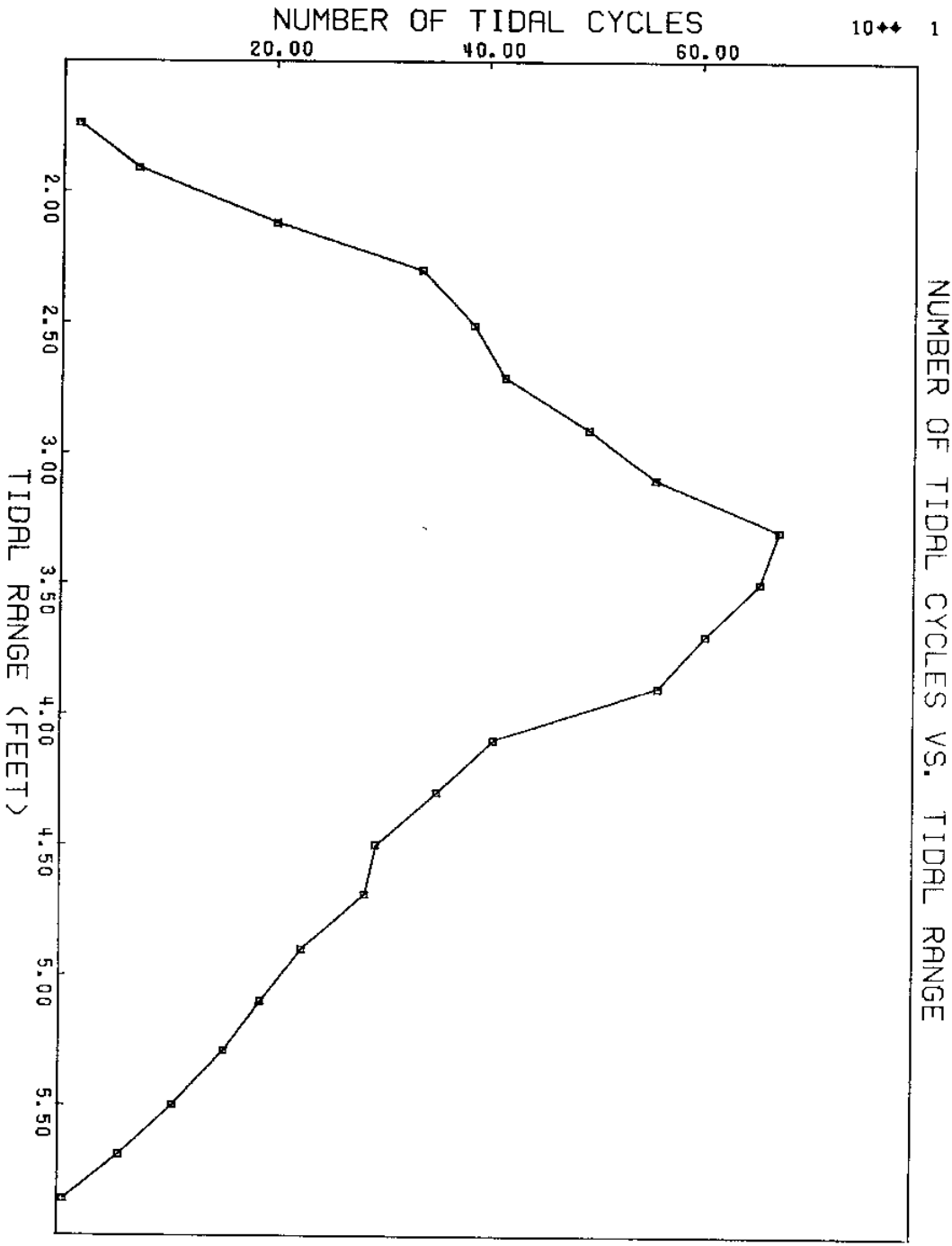
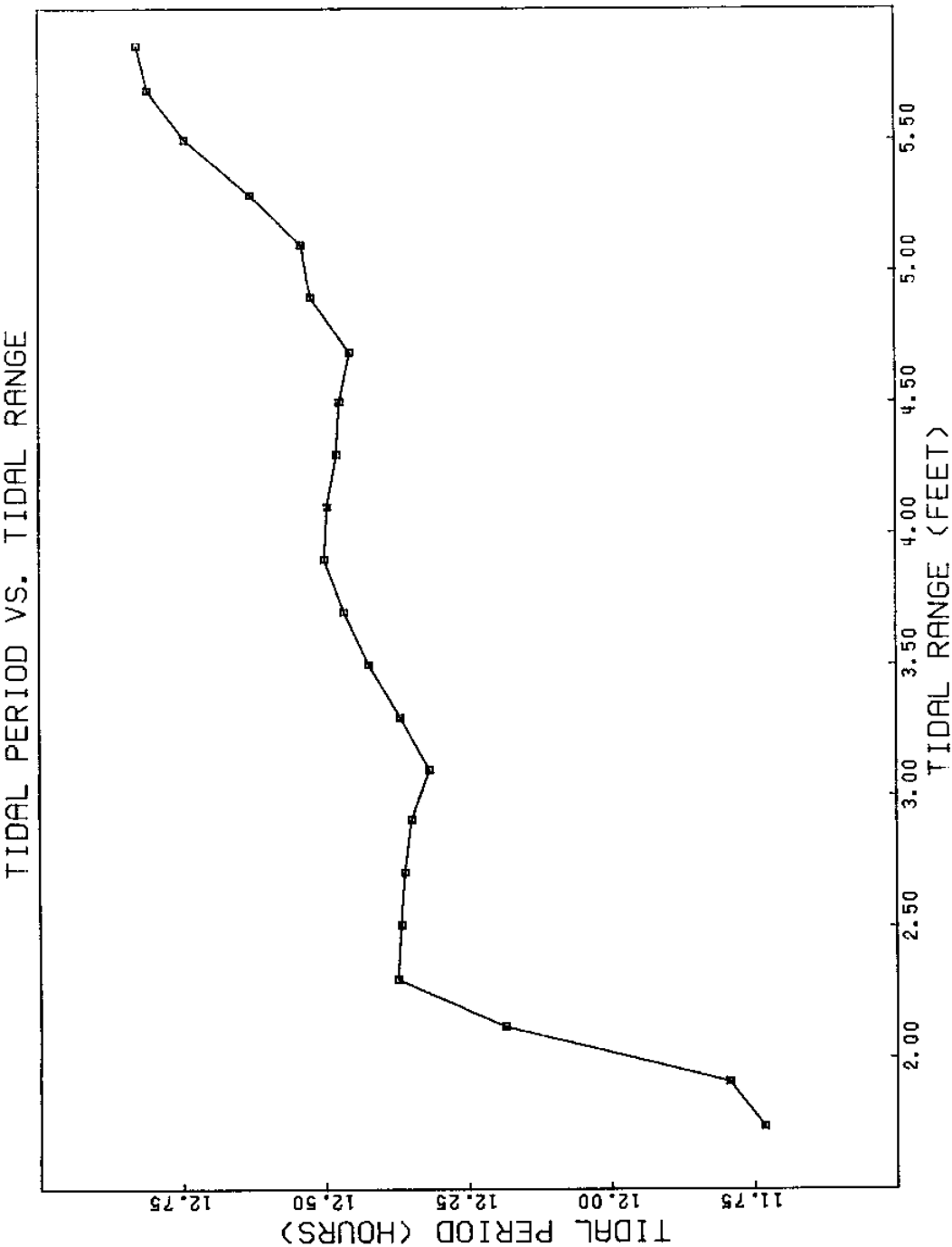

TIDAL CYCLE VARIATION
1.6 TO 1.8 FOOT RANGE
MEAN RANGE
5.8 TO 6.0 FOOT RANGE
TIDAL HEIGHT (FEET)
3.00
2.00
1.00
0.00
-1.00
-2.00
2.00
4.00
6.00
8.00
10.00
12.00
TIME (HOURS)


NUMBER OF TIDAL CYCLES
10** 1
20.00
40.00
60.00
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
TIDAL RANGE (FEET)
NUMBER OF TIDAL CYCLES VS. TIDAL RANGE


TIDAL PERIOD VS. TIDAL RANGE
TIDAL PERIOD (HOURS)
11.75
12.00
12.25
12.50
12.75
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
TIDAL RANGE (FEET)

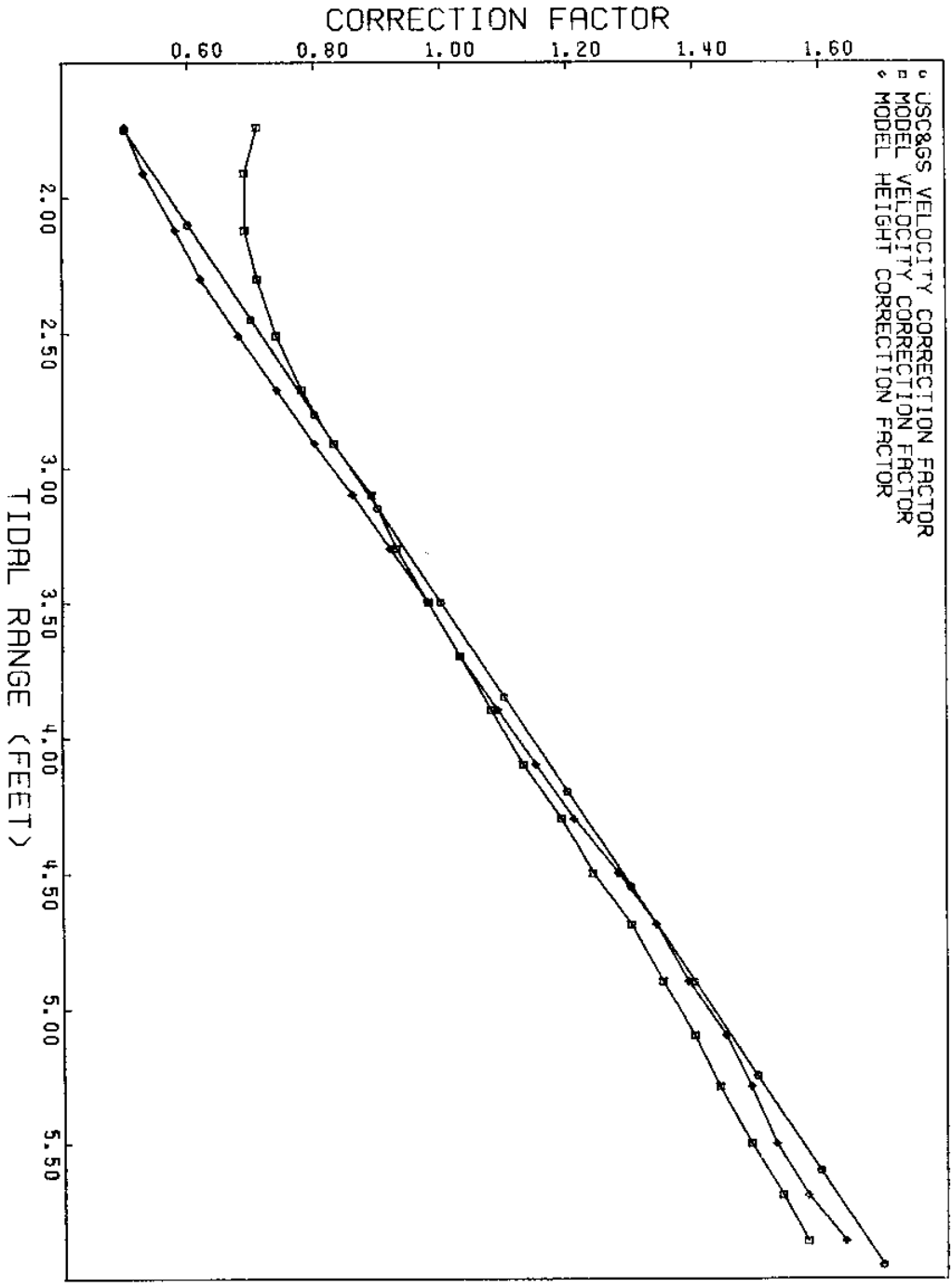

CORRECTION FACTORS VS. TIDAL RANGE
CORRECTION FACTOR
0.60
0.80
1.00
1.20
1.40
1.60
USC&GS VELOCITY CORRECTION FACTOR
MODEL VELOCITY CORRECTION FACTOR
MODEL HEIGHT CORRECTION FACTOR
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
TIDAL RANGE (FEET)

TABLE 1

TIDAL CONSTITUENT PARAMETERS AT MOUTH OF NARRAGANSETT BAY

CONSTITUENT	AMPLITUDE	EPOCH	SPEED
M_2	1.5000	214.6	28.9841042
S_2	0.3720	231.3	30.0000000
N_2	0.4030	201.0	28.4397295
M_4	0.1500	76.0	57.9682084
K_1	0.2020	93.1	15.0410686
S_a	0.1820	143.1	0.0410686
O_1	0.1624	129.0	13.9430356
K_2	0.0960	235.2	30.0821373
2	0.0770	210.0	27.9682084
V_2	0.0660	198.5	28.5125831
P_1	0.0660	103.6	14.9589314
$2N_2$	0.0538	187.7	27.8953548
Q_1	0.0430	111.8	13.3986609
S_1	0.0380	46.9	15.0000000
L_2	0.0370	187.2	29.5284789
T_2	0.0216	231.3	29.9589333
M_6	0.0200	68.0	86.9523127

REFERENCES

Hess, K.W. and F.M. White, "A Numerical Tidal Model of Narragansett Bay", Ocean Engineering, University of Rhode Island, Marine Technical Report No. 20, 1974.

Leenderstee, J.J., "Aspects of a Computational Model for Long Period Water Wave Propagation", Rand Corporation, Santa Monica, California, Memorandum No. RM 5294-PR, May 1967.

Haight, F.J., "Currents in Narragansett Bay, Buzzards Bay, and Nantucket and Vineyard Sound", U.S. Coast and Geodetic Survey Special Publication No. 208, 1936.

Swanson, C. and M. Spaulding, "Tides and Tidal Currents of Narragansett Bay", Ocean Engineering, University of Rhode Island, Marine Technical Report No. 35, 1975.

U.S. Department of Commerce, "Tidal Currents in Narragansett Bay", National Ocean Survey, 1971.

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